PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 24 July 2000 (24.07.00)	
International application No. PCT/AU99/01028	**Applicant's or agent's file reference**
International filing date (day/month/year) 19 November 1999 (19.11.99)	**Priority date** (day/month/year) 18 December 1998 (18.12.98)
Applicant TAPANES, Edward, E. et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

28 June 2000 (28.06.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Claudio Borton
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

15

Applicant's or agent's file reference FP11742	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International application No. **PCT/AU99/01028**	International filing date *(day/month/year)* 19 November 1999	Priority Date *(day/month/year)* 18 December 1998
International Patent Classification (IPC) or national classification and IPC **Int. Cl.** [7] G01N 21/63, G01M 11/00		
Applicant FUTURE FIBRE TECHNOLOGIES PTY LTD et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 7 sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[ ]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[ ]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[ ]	Certain observations on the international application

Date of submission of the demand 28 June 2000	Date of completion of the report 17 October 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **MANO RAMACHANDRAN** Telephone No. (02) 6283

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU99/01028

I. Basis of the report

1. With regard to the **elements** of the international application:*

- [ ] the international application as originally filed.
- [X] the description, pages **1-35,** as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [ ] the claims, pages , as originally filed,
  pages , as amended (together with any statement) under Article 19,
  pages **37** received on **14 August 2000** with the letter of **14 August 2000**
  pages **36,38,39,40,41,42** , received on **21 September 2000** with the letter of **21 September 2000**
- [X] the drawings, pages **1-4,** as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [ ] the sequence listing part of the description:
  pages , as originally filed
  pages , filed with the demand
  pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

- [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3(b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:

- [ ] contained in the international application in written form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form.
- [ ] furnished subsequently to this Authority in computer readable form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages
   - [ ] the claims, Nos.
   - [ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-28	YES
	Claims		NO
Inventive step (IS)	Claims	1-28	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-28	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

None of the citations listed in the ISR discloses an apparatus or a method of locating the position of an event by launching counter propagating optical signals from a single light source into a wave guide from the two ends of the wave guide simultaneously, said counter propagating signals modified by the event continue to propagate along the waveguide and detected at the two ends to determine the time difference between the receipt of the modified counter propagating signals in order to locate the position of the event as claimed.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1.(Amended) An apparatus for monitoring a structure and for locating the position of an event including;

a light source;

a waveguide for receiving light from the light source so that the light is caused to propagate in both directions along the waveguide to thereby provide counter-propagating optical signals in the waveguide, the waveguide being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by an external parameter caused by or indicative of the event to provide modified counter-propagating optical signals which continue to propagate along the waveguide; and

detector means for detecting the modified counter-propagating optical signals effected by the parameter and for determining the time difference between the receipt of the modified counter-propagating optical signals in order to determine the location of the event.

2. The apparatus of claim 1 wherein the waveguide is a silica waveguide.

3. The apparatus of claim 1 or 2 wherein light source is for launching simultaneously into opposite ends of the waveguide.

4. The apparatus of any one of claims 1 to 3 wherein the light source is a single light source.

5. The apparatus of any one of claim 1 to 4 wherein the waveguide is one or more optical fibres which forms an event sensitive optical fibre.

6. The apparatus of any one of claims 1 to 5 wherein further silica waveguides are conn cted to the said waveguide at either or both ends in order to add

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additional delay between the transmissive counter-propagating signals and to provide insensitive lead waveguides.

10 7. The apparatus of any one of claims 1 to 6 wherein the detector means comprises:

first and second photodetectors for simultaneously receiving the radiation from the counter-propagating signals in the waveguide; and

15 processing means for receiving signals from the first and second photodetectors for determining the time delay or difference between the signals effected from the same disturbance and therefore determining the location of the sensed event.

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8. The apparatus of claim 7 wherein a waveguide coupler or set of couplers is arranged between the light source and the photodetectors and the silica waveguide so that the light can be simultaneously transmitted from the

25 light source to both ends of the silica waveguide and the detector means also being connected to the coupler or couplers so that the counter-propagating transmissive radiation can be directed via the coupler or couplers from the silica waveguide to the detector means.

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9. The apparatus of any one of claims 1 to 8 wherein the waveguide is for connection to the structure to monitor the structure.

35 10. The apparatus of anyone of claims 1 to 8 wherein the structure comprises the waveguide for transmitting data along the waveguide from one place to another and the

waveguide simultaneously receiving the light from the light source to provide th counter-propagating optical signals so as to enable the integrity and security of the waveguide to be monitored.

11. The apparatus according to any one of claims 1 to 10 wherein the detector also identifies or quantifies the parameter from the modified counter-propagating optical signals.

12. The apparatus of any one of claims 1 to 11 wherein waveguide is arranged in a loop configuration so that light can be simultaneously launched into both ends of the waveguide from a single light source.

13.(Amended) The apparatus of claim 11 wherein data signals are suppled to the waveguide so that the waveguide acts as a communication link for transmission of data from one place to another and the launching of the counter-propagating optical signals in the waveguide enables the integrity and security of the waveguide to be monitored.

14.(Amended) The apparatus according to claim 11 wherein the waveguide is applied to a structure to monitor the structure.

15.(Amended) A method for monitoring a structure to locate the position of an event, including the steps of;

launching light into a waveguide so that the light is caused to propagate in both directions along the waveguide to thereby provide counter-propagating optical signals in the waveguide, the waveguide being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by an external parameter caused by the event, to provide modified counter-propagating optical signals which continue to propagate along the waveguide; and

detecting the modified counter-propagating optical signals effected by the parameter and for determining the time differenc betwe n the receipt of the modified signals in order to determine the location of the event.

16. The method of claim 13 wherein the light is launched into both ends of the waveguide to provide the counter-propagating signals.

17. The method of claim 13 wherein the light is launched into both ends of the waveguide from a single light source.

18. The method according to claim 11 wherein the parameter is quantified and/or identified from the modified signals.

19.(Amended) A waveguide transmissive counter-propagating signal method for locating events in optical waveguides, which may include:

providing a sensing optical fibre formed from a waveguide material designed to simultaneously transmit counter-propagating optical signals;

providing a detector for locating events in optical waveguides,;

providing a lead optical fibre formed from a waveguide material which acts as an insensitive light guide between the sensing fibre and detector;

providing a lead optical fibre formed from a waveguide material which acts as an insensitive light guide between the sensing fibre and a light source;

connecting the sensor waveguide and the lead optical fibres so that cores of the waveguides are aligned and remain fixed at the splice;

launching counter-propagating light signals into th sensing optical fibre and lead optical fibres, which light signals are modified upon disturbance of the sensing

optical fibre so that modified counter propagating optical signals continue to propagate along the sensing fibre;

delivering the modifi d counter-propagating signals from the waveguide fibre, via the lead optical fibres, to the detector so the time difference between the receipt of the modified counter-propagating signals may be measured and utilised to determine the location of the sensed event; and

registering any changes in the waveguide sensor optical signals so that the sensed parameter may be quantified and/or identified.

20.(Amended) An apparatus for monitoring an optic fibre communication link into which data signals are launched and from which the data signals are received, and for locating the position of a disturbance to the link including;

a light source for launching light into the link so that the light is caused to propagate in both directions along the link to thereby provide counter-propagating optical signals in the link, the link being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by the disturbance to provide modified counter-propagating optical signals which continue to propagate along the link; and

detector means for detecting the modified counter-propagating optical signals and for determining the time difference between the receipt of the modified counter-propagating optical signals in order to determine the location of the disturbance.

21. The apparatus of claim 20 wherein the link is a silica waveguide.

22. The apparatus of claim 20 or 21 wherein the light source is for launching simultaneously into opposite ends of th link.

23. The apparatus of any one of claims 20 to 22 wherein the light source is a single light source.

24. The apparatus of any one of claims 20 to 23 wherein the detector means comprises:

first and second photodetectors for simultaneously receiving the light from the counter-propagating signals in the link; and

processing means for receiving signals from the first and second photodetectors for determining the time delay or difference between the signals effected from the same disturbance and therefore determining the location of the disturbance.

25. The apparatus of claim 24 wherein a waveguide coupler or set of couplers is arranged between the light source and the photodetectors and the link so that the light can be simultaneously transmitted from the light source to both ends of the link and the detector means also being connected to the coupler or couplers so that the counter-propagating signals can be directed via the coupler or couplers from the link to the detector means.

26.(Amended) A method for monitoring an optical fibre communication link into which data signals are launched and from which the data signals are received, to locate the position of a disturbance to the link, including the steps of;

launching light into the link so that the light is caused to propagate in both directions along the link to thereby provide counter-propagating optical signals in the link, the link being capable of having the counter-propagating optical signals or some characteristic of the

signals modified or effected by the disturbance to provide modified counter-propagating optical signals which continue to propagate along the link; and

detecting the modified counter-propagating optical signals effected by the disturbance and for determining the time difference between the receipt of the modified signals in order to determine the location of the disturbance.

27. The method of claim 26 wherein the light is launched into both ends of the link to provide the counter-propagating signals.

28. The method of claim 26 wherein the light is launched into both ends of the link from a single light source.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for monitoring a structure and for locating the position of an event including;

a light source;

a waveguide for receiving light from the light source so that the light is caused to propagate in both directions along the waveguide to thereby provide counter-propagating optical signals in the waveguide, the waveguide being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by an external parameter caused by or indicative of the event to provide modified counter-propagating optical signals; and

detector means for detecting the modified counter-propagating optical signals effected by the parameter and for determining the time delay or difference between the modified counter-propagating optical signals in order to determine the location of the event.

2. The apparatus of claim 1 wherein the waveguide is a silica waveguide.

3. The apparatus of claim 1 or 2 wherein light source is for launching simultaneously into opposite ends of the waveguide.

4. The apparatus of any one of claims 1 to 3 wherein the light source is a single light source.

5. The apparatus of any one of claim 1 to 4 wherein the waveguide is one or more optical fibres which forms an event sensitive optical fibre.

6. The apparatus of any one of claims 1 to 5 wherein further silica waveguides are connected to the said waveguide at either or both ends in order to add

additional delay between the transmissive counter-propagating signals and to provide insensitive lead waveguides.

7. The apparatus of any one of claims 1 to 6 wherein the detector means comprises:

first and second photodetectors for simultaneously receiving the radiation from the counter-propagating signals in the waveguide; and

processing means for receiving signals from the first and second photodetectors for determining the time delay or difference between the signals effected from the same disturbance and therefore determining the location of the sensed event.

8. The apparatus of claim 7 wherein a waveguide coupler or set of couplers is arranged between the light source and the photodetectors and the silica waveguide so that the light can be simultaneously transmitted from the light source to both ends of the silica waveguide and the detector means also being connected to the coupler or couplers so that the counter-propagating transmissive radiation can be directed via the coupler or couplers from the silica waveguide to the detector means.

9. The apparatus of any one of claims 1 to 8 wherein the waveguide is for connection to the structure to monitor the structure.

10. The apparatus of anyone of claims 1 to 8 wherein the structure comprises the waveguide for transmitting data along the waveguide from one place to another and the waveguide simultaneously receiving the light from the light source to provide the counter-propagating optical signals so as to enable the integrity and security of the waveguide to be monitor d.

11. The apparatus according to any one of claims 1 to 10 wherein the detector also identifies or quantifies the parameter from the modified counter-propagating optical signals.

12. The apparatus of any one of claims 1 to 11 wherein waveguide is arranged in a loop configuration so that light can be simultaneously launched into both ends of the waveguide from a single light source.

13. The method of claim 11 wherein data signals are suppled to the waveguide so that the waveguide acts as a communication link for transmission of data from one place to another and the launching of the counter-propagating optical signals in the waveguide enables the integrity and security of the waveguide to be monitored.

14. The method according to claim 11 wherein the waveguide is applied to a structure to monitor the structure.

15. A method for monitoring a structure to locate the position of an event, including the steps of;

launching light into a waveguide so that the light is caused to propagate in both directions along the waveguide to thereby provide counter-propagating optical signals in the waveguide, the waveguide being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by an external parameter caused by the event, to provide modified counter-propagating optical signals; and

detecting the modified counter-propagating optical signals effected by the parameter and for determining the time delay or difference between the modified signals in ord r to determine the location of the ev nt.

16. The method of claim 13 wherein the light is launched into both ends of the waveguide to provide the counter-propagating signals.

17. The method of claim 13 wherein the light is launched into both ends of the waveguide from a single light source.

18. The method according to claim 11 wherein the parameter is quantified and/or identified from the modified signals.

19. A waveguide transmissive counter-propagating signal method for locating events in optical waveguides, which may include:

providing a sensing optical fibre formed from a waveguide material designed to simultaneously transmit counter-propagating optical signals;

providing a detector for locating events in optical waveguides, designed to optimise the sensor sensitivity and detection capabilities;

providing a lead optical fibre formed from a waveguide material which acts as an insensitive light guide between the sensing fibre and detector;

providing a lead optical fibre formed from a waveguide material which acts as an insensitive light guide between the sensing fibre and a light source;

fusion splicing, or otherwise connecting, the sensor waveguide and the lead optical fibres so that cores of the waveguides are aligned and remain fixed at the splice;

delivering the counter-propagating signals from the waveguide sensor, via the lead optical fibres, to the detector so the time delay or difference between the signals may be measured and utilised to determine the location of the sensed event; and

registering any changes in the waveguide sensor optical signals so that the sensed parameter may be quantified and/or identified.

20. An apparatus for monitoring an optic fibre communication link into which data signals are launched and from which the data signals are received, and for locating the position of a disturbance to the link including;

a light source for launching light into the link so that the light is caused to propagate in both directions along the link to thereby provide counter-propagating optical signals in the link, the link being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by the disturbance to provide modified counter-propagating optical signals; and

detector means for detecting the modified counter-propagating optical signals and for determining the time delay or difference between the modified counter-propagating optical signals in order to determine the location of the disturbance.

21. The apparatus of claim 20 wherein the link is a silica waveguide.

22. The apparatus of claim 20 or 21 wherein the light source is for launching simultaneously into opposite ends of the link.

23. The apparatus of any one of claims 20 to 22 wherein the light source is a single light source.

24. The apparatus of any one of claims 20 to 23 wherein the detector means comprises:

first and second photodetectors for simultaneously receiving the light from the counter-propagating signals in the link; and

processing means for receiving signals from the first and second photodetectors for determining the time delay or difference between the signals effected from the same disturbance and therefore determining the location of the disturbance.

25. The apparatus of claim 24 wherein a waveguide coupler or set of couplers is arranged between the light source and the photodetectors and the link so that the light can be simultaneously transmitted from the light source to both ends of the link and the detector means also being connected to the coupler or couplers so that the counter-propagating signals can be directed via the coupler or couplers from the link to the detector means.

26. A method for monitoring an optical fibre communication link into which data signals are launched and from which the data signals are received, to locate the position of a disturbance to the link, including the steps of;

launching light into the link so that the light is caused to propagate in both directions along the link to thereby provide counter-propagating optical signals in the link, the link being capable of having the counter-propagating optical signals or some characteristic of the signals modified or effected by the disturbance to provide modified counter-propagating optical signals; and

detecting the modified counter-propagating optical signals effected by the disturbance and for determining the time delay or difference between the modified signals in order to determine the location of the disturbance.

27. The method of claim 26 wherein the light is launched into both ends of the link to provide the counter-propagating signals.

28. The method of claim 26 wherein the light is launched into both ends of the link from a single light source.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 99/01028

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: G01N 21/63,G01M 11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI,JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Patent Abstracts of Japan, P-421, page165, JP 60-169775 A (SUMITOMO DENKI KOGYO K.K) 3 September 1985	
X	Abstract	1,3-5,7-12,15-18
Y		2,6,13,14,19
	Patent Abstract of Japan, P-103, page 109, JP 56-150323 A (NIPPON DENKI K.K) 20 November 1981	
X	Abstract	1,3,5-11,13-16,18-20, 22,24-27
Y		2,4,12,17,21,23,28
	Patent Abstract of Japan, P-1693, page 100, JP 05-297052 A (FURUKAWA ELECTRIC CO LTD) 12 November 1993	
Y	Abstract	1-28

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 January 2000	21 JAN 2000
Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	MANO RAMACHANDRAN Telephone No.: (02) 6283 2166

INTERNATIONAL SEARCH REPORT

International application No. PCT/AU 99/01028

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Patent Abstract of Japan, P-361, page 118, JP 60-14137 A (NIPPON DENKI K.K)24 January 1985 Abstract	1-28
Y	Derwent Abstract Accession No. 98-372020/32, Class X12, JP 10-148654 A (DENRYOKU CHUO KENKYUSH0) 2 June 1998 Abstract	1-28
Y	Derwent Abstract Accession No. 99-013451/02, Class V07, JP 10-281923 A (MITSUBISHI JUKOGYO K.K) 23 October 1998 Abstract	1-28
A	US 5627637 A (KAPTEYN) 6 May 1997 Abstract	
A	US 5356220 A (IIDA et al) 18 October 1994 Abstract	
A	US 5026141 A (GRIFFITHS) 25 June 1991 Abstract	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 99/01028

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5356220	AU	39820/93	JP	60-03197	EP	572238
		JP	53-32850	DE	69321160		
US	5026141	US	4927232	US	4812645	US	4654520

END OF ANNEX

3. Detailed description of the invention

(1) Field of application of the invention

This invention relates to a device for detecting the locations of faults or detecting faults in power transmission lines due to snowfalls or earthquakes or the like affecting power transmission lines such as overhead transmission lines or ducted aerial transmission lines.

(2) Prior art

A fault location detection device for power transmission lines, as illustrated in Figure 1, detects the location of the fault by means of the difference in the propagation delay time at the two ends when a surge wave is propagated along the power transmission line **1** when a fault occurs at the fault position **F**, and requires sensors **2** in order to detect the surge wave at each end, signal processing devices **3** to process the signals from the sensors **2**, and a synchronous signal transmission circuit **4** that employs microwave circuits and the like in order to measure the time difference between the two devices. The signal processing device measures the time of arrival of the surge wave on the basis of the synchronous signals, and calculates the location of the fault from the differences in the times of arrival at the two ends and the velocity of propagation of the surge wave along the transmission line. In this case, the velocity of propagation of the surge wave is approximately the velocity of light, and the measurement of the differences in the time of arrival must be made very accurately, and moreover, a method of synchronization is required for the signal processing devices at the two ends.

(3) Deficiencies of the prior art

The synchronous signals that form the basis when the times of arrival of the surge waves at the two ends are very important in fault point detection devices, but the microwave circuits that transmit the synchronous signals also involve transmission delay, and hence it is first necessary to calculate the synchronous signal transmission delay time. However, because it is impossible to measure the transmission delay time from end A to end B or from end B to end A, the transmission delay time for a synchronous signal from end A to end B, or from end B to end A, is taken to be one half of the delay time when a signal is sent from end A to end B and the signal is turned at end B and is sent back again to end A. In this method, the transmission delay time must be calculated at each point at which a detection device is disposed, and the constant must be set for the signal processing device. Moreover, in this method, the transmission delay time from point A to point B need not necessarily be the same as the transmission delay time from point B to point A. Furthermore, the capital cots of this method is high because it requires high speed and high accuracy synchronous signal processing devices are required at both ends.

(4) Objectives of the invention

It is an objective of the present invention to overcome such problems of the prior art, to simplify the signal processing circuit, to improve the accuracy of the determination of the locations of faults, and to render unnecessary the calculation of the transmission delay-time.

(5) Constitution of the invention

Figure 2 illustrates the main elements of the constitution of the fault location detection device envisaged by the present invention. **1** is the power transmission line, and the device consists of sensors **2** that detect surge waves at the two ends, and an electrical/optical converter (hereinafter referred to as an 'E/O converter') **6** that converts the output from the sensors into light, and fibre optic cable **7** that transmits the optical signals, and a signal processing device **8** that processes the optical signals from the two ends and calculates the position of the location of the fault **F**. In this case, the sensors consist of CTs (current transformers) or known art. Moreover, the propagation delay time difference for the optical signals from the two ends can be calculated beforehand and is known.

(6) Practical embodiment

The following is an explanation of the use of a practical embodiment of the fault location detection device illustrated in Figure 2. A surge wave that is generated from fault location point **F** at distance l_A from end A and at distance l_B from end B is propagated towards both ends at velocity v and is converted into optical signals by the sensors and the E/O converters, and is propagated along the optical fibre. In this case, the signal propagation delay times on the optical fibre for end A and end B are respectively τ_A and τ_B, and on the basis of the time at which the surge wave was generated, the times t_A and t_B respectively at which the surge wave signals from the two ends arrive at the signal processing device are provided by the following formulas:

$$t_A = l_A/v + \tau_A + \alpha$$
$$t_B = l_B/v + \tau_B + \alpha \quad (1)$$

In this case, α is the propagation delay time for a signal in the sensor **2**, the E/O converter **6** and the signal processing device **8**, and is the same value at each end. If the centre between ends A and B and is 0, and end A is a positive value from the centre and end B is a negative value from the centre, then the following formula for x may be derived from formula (1):

$$x = (l_B - l_A)/2 = (t_B - t_A + (\tau_A - \tau_B))\cdot v/2? \quad (2)$$

As τ_A and τ_B are known in this case, the location of the fault x can be calculated by measuring the difference in the signal delay time ($t_B - t_A$) for the surge waveform from the two ends.

Figure 3 shows specifically the internal circuit from the signal processing device **8** in Figure 2, wherein the optical signals for the surge waveforms from the two ends are converted by an optical/electrical converter (hereinafter referred to as an 'O/E

converter') into electrical signals which are input into the trigger circuit **10**. When the surge waveform exceeds a specified threshold value, the trigger circuit sets its output signals to ON. These signals set the R-S flip-flop **11** and output *Q* to ON and output $\overline{Q}$ to OFF. Consequently, if the surge waveform arrives at end A first, the A end side input *Q* of the AND gate **12** is ON and the output from the B end side $\overline{Q}$ is ON until the surge waveform reaches end B and switches to OFF at the point when the surge waveform reaches end B, and hence the output of the AND gate **12** is ON when the surge waveform reaches end A first and until the surge waveform then reaches end B. In all other cases, it is always OFF.

On the other hand, when the surge waveform reaches end B first, and the surge waveform then reaches end A later, the output from the AND gate **13** is ON after the surge waveform reaches end B and until the surge waveform reaches end A. The R-S flip-flop **11a** is set by the output from the AND gate **12**, and is reset by the output from the AND gate **13**. Consequently, the output *Q* from the R-S flip-flop **11a** is ON only when the surge waveform reaches end A first. The OR gate **14** is ON when the surge waveform reaches end A or B first and until the surge waveform then reaches end B or end A. While the output from the OR gate **14** is ON only, the up/down counter **16** increments or decrements the output clock of the clock generator circuit **15** according to whether the output signals from the R-S flip-flop **11a** are ON or OFF. Moreover, if a clock number equivalent to the offset time in formula (2) (τ_A - τ_B) is loaded beforehand into the up/down counter **16**, the location of the fault is at the centre if the count value is 0, and on the A end side if the count value is positive, or at the B end side is the count value is negative. The fault location calculation circuit **17** detects that a fault has occurred when the output from the OR gate **14** is ON, and then, when the output from the OR gate **14** is OFF, the fault location calculation circuit **17** reads the count value and converts the count value into a distance according to formula (2), and outputs the distance.

(7) Effects

The fault location detection device envisaged by the present invention renders unnecessary the synchronous signals that are required by devices of the prior art and hence enables the use of a very simple signal processing circuit, while the use of optical fibre for the transmission of the signals improves the resistance of the device to noise and protects the signal processing device from the effects of surges. Moreover, a further advantage of the present invention is that the measurement of the synchronous signal propagation delay time at the position at which the detection device was disposed is not required. More particularly, in the case of ducted aerial power transmission lines, where the distance between end A and end B is several tens of meters, the use of equal lengths of optical fibre from the two ends to the signal processing device eliminates the effect of the offset time from formula (2) (τ_A - τ_B), and thus enables the determination of the locations of faults with great accuracy.

4. Simplified description of the diagrams ....